Seven Years on from Deep Water Horizon – How the Global Industry has Applied the Learning from the Response

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The Macondo blow-out in the Gulf of Mexico in 2010, and the earlier Montara incident in Australia, led the oil and gas industry to fundamentally reappraise both drilling safety and preparation for oil spills. The Deepwater Horizon response in particular had resulted in a series of innovations. As a result the International Oil and Gas Producers Association (IOGP) established a multi-year programme to capture the learning from these and similar incidents, and to enhance future prevention and preparedness.

The resulting programmes have now been completed, including a joint industry project managed by IPIECA to incorporate the learning from the response and subsequent technical studies into a fully revised and updated suite of oil spill preparedness support resources. This presentation will highlight some of the key outputs from the global programme including:

- Sub-sea well response systems available in strategic locations around the world, including equipment for capping and containment and sub-sea dispersant application
- The latest updated guidance and tools for emergency planning, including:
    - Risk based planning scenarios
    - Response strategy optimisation using Net Environmental Benefit Analysis (NEBA)
    - Tiered Preparedness and Response principles for cascading local, regional and global resources to any scale
    - A common Incident Management System (IMS) for the oil and gas industry
    - Stakeholder engagement throughout the lifecycle
- Fully updated technical guidance on response tools and techniques, including:
    - Dispersant application both on the surface and sub-sea
    - Controlled in-situ burning of crude oil on the sea surface
    - Managing oiled wildlife response
    - Oil spill surveillance, monitoring and modelling
    - ‘Common Operating Picture’ information systems to support planning and response

These technical resources can now be accessed free of charge from IOGP and IPIECA.

Introduction

The well incidents at Macondo in the Gulf of Mexico in 2010 and Montara in 2009 were followed by a major global effort to capture the learning, enhance drilling safety, and improve emergency preparedness and response. The enormous scale and technical complexity of the Gulf of Mexico response drove innovations in both response technology and the management of major emergencies. More than 150 companies and multiple government agencies were engaged in the response, all under the overall direction of the US Coastguard in the Unified Command:

- Unique sub-sea operations, including capping and containment, were conducted about 80 km from shore, in around 1,500 m of water, at sea bottom temperatures of about 3 degrees Centigrade and pressures over 150 bar
- Over 48,000 responders were mobilized across 5 US States along the Gulf of Mexico coast
- Over 6,500 vessels and up to 120 aircraft per day were deployed during the response
- Over 4,000,000 m of boom were deployed
- Around 50 surface vessels and up to 16 Remotely Operated Vehicles were operated within a tight radius of a mile over the well site, all managed by large-scale simultaneous operations.

The well flowed for 87 days before being capped on 15th July 2010 and this was the largest spill response in history. Many innovative techniques were developed and applied for the first time at this scale. These included:

- Sub-sea dispersant injection to disperse oil at the well head
- Controlled burning of oil slicks on the sea surface for extended periods
- Satellites, infra-red and ocean vehicles for spill tracking and sea monitoring
- ‘Common Operating Picture’ information systems used to manage huge amounts of disparate data in support of the response

Government and Industry Response Programmes

Companies, governments, regulators and trade associations, at the regional and global level, moved quickly to capture the learning from these events and develop new capabilities. For example:

- The US Marine Well Containment Corporation was established to provide capping and containment technology for the Gulf of Mexico (GOM-COS, 2016). The Centre for Offshore Safety was set up to promote excellence and continuous improvement in safety and operational integrity in US Outer Continental Shelf oil and gas activities. The complementary technical programme of the American Petroleum Institute included updated guidance on management systems and equipment such as blowout preventers.
- The UK Oil Spill Prevention and Response Advisory Group (OSPRAG) was formed by the offshore oil and gas industry, its regulators and the trade unions, and its programme included enhancing technical practices throughout the well life cycle and improvements to the spill response toolkit. For example, 2011 saw the manufacture and testing of a sub-sea well capping device.

IOGP, as the global forum of the companies that produce oil and gas, led the initiative to identify and implement improvements to the safety of offshore operations in general and to deep water drilling in particular (IOGP, 2011). This work, which began in July 2010, was called the Global Industry Response Group (GIRG). This brought together more than 100 technical experts and managers from some 20 companies around the world for almost a year. Their recommendations led to multi-year programmes on well incident prevention, subsea well intervention (including capping and containment) and oil spill response and preparedness. These were coordinated with other industry programmes around the world to align efforts and minimise duplication. This paper will mainly focus on emergency and preparedness and oil spill response, but for completeness a brief summary on well safety developments is included.

Well Safety and Incident Prevention

The IOGP Wells Expert Committee's programme on incident prevention (IOGP, 2015) resulted in:

- Significant improvements to training, both in the class room and on the job, to reduce the risks of human error in well management by focusing on the role of human factors in major technical incidents (IOGP, 2016a)
- Establishing an industry-wide well control incident database that enables operators to learn from each other and share challenges and progress
- Measurable improvements in the reliability of equipment to prevent well blow-outs by setting up a dedicated reliability task force
- Developing and implementing key international standards for well design and operations management (IOGP, 2016b)

This work has been complementary to other industry efforts to apply the the learning from the incidents, and to further enhance and accelerate the application of process safety management principles to a broad range of major accident scenarios. Key focus areas have included:

- Development and application of safety and environmental management systems
- Application of risk management tools, such as HAZOP, Bow-Tie and Barrier analysis, and Layer of Protection Analysis (LOPA)
- Sharing and learning from incidents
- Leading and lagging performance indicators
- Auditing and assurance
- Safety culture and human factors

The industry has also sought to incorporate learning from other industries, such as: '*Crew Resource Management'* (IOGP, 2014), which applies concepts from aviation safety to well operations.

Subsea Well Response Project

One of the most tangible legacies from the IOGP programme was from the Subsea Well Response Project (SWRP). This was progressed by an alliance of nine oil and gas companies in partnership with Oil Spill Response Limited (OSRL). The project involved significant investment for research, development and construction, and has resulted in a global network of well capping devices and ancillary hardware for use in the event of a subsea well incident. OSRL's integrated, global subsea well intervention system (SWIS) now includes four capping systems in strategic locations around the world:

- Two 18 3/4" bore capping stacks developed to handle pressure up to 15kpsi (Brazil and Norway)
- Two 7 1/16" bore capping stacks designed for pressure up to 10kpsi (Singapore and South Africa)

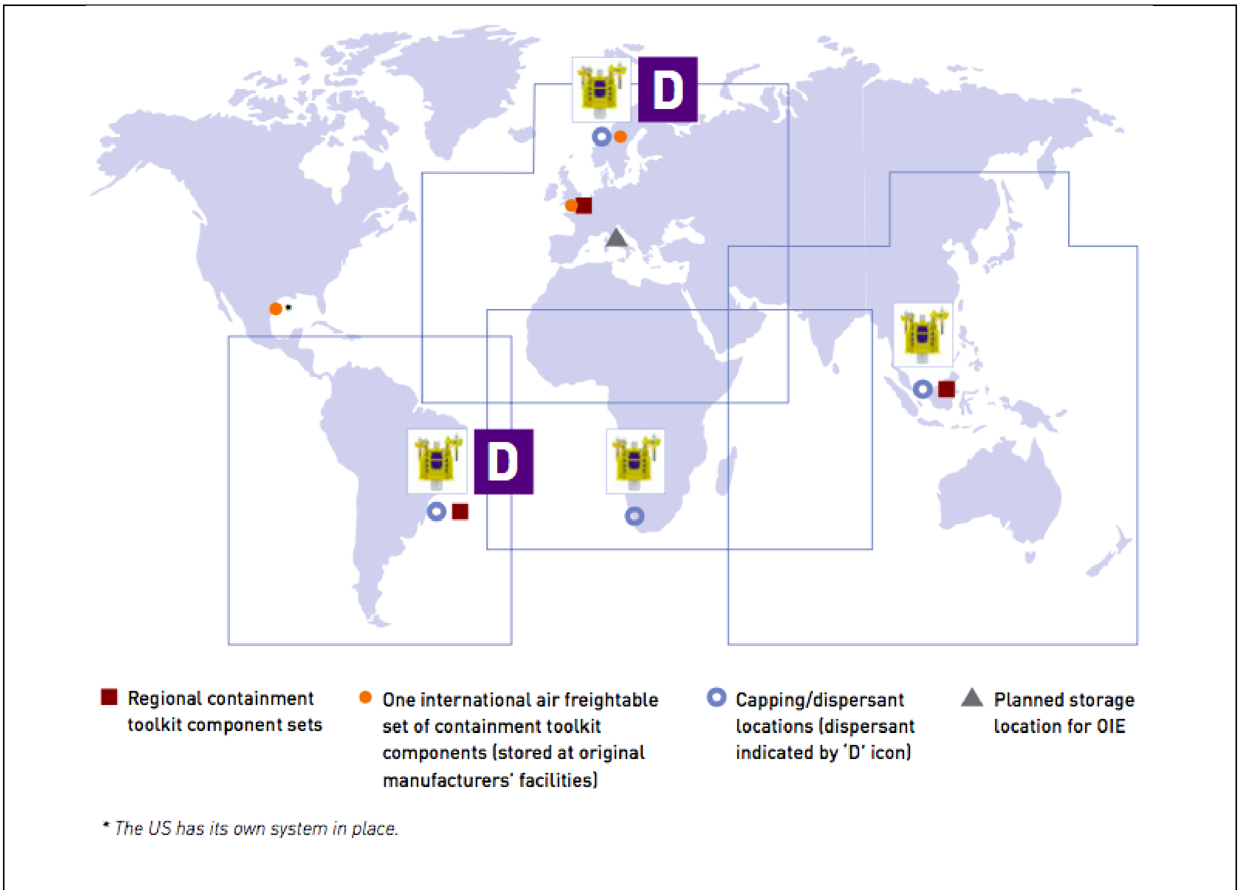

Figure 1. New well capping and containment facilities from the IOGP Subsea Well Response Project (Source: IOGP)

The well containment toolkit includes standard, long lead components, which can be used with standard industry hardware to create the containment system as needed. If well shut-in is not possible, this system can bring flowing hydrocarbons from a wellhead to the surface in a safe and controlled way, ready for storage or disposal. This containment toolkit is stored in strategic locations around the world. This includes flexible subsea jumpers and flow-lines stored in the UK, Brazil and Singapore for onward transportation. The remaining containment toolkit components can be airfreighted and are stored at the original equipment manufacturers in the UK, USA and Norway.

Two supplementary hardware kits, which include equipment for subsea application of dispersant at a flowing wellhead, include:

- Tools for site surveys prior to intervention work (e.g. 2D and 3D sonar)
- Debris clearing equipment to gain access to a BOP, if needed
- Flying leads, distribution manifold and dispersant wands capable of injecting dispersant at multiple subsea locations
- High pressure, high volume accumulators for closing an existing BOP

Offset installation equipment is being developed and tested for use where vertical well access is not feasible. This will enable responders to remove debris, or install capping and containment equipment at a safe distance from an incident site. For more information on the subsea well response project visit: *http://subseawellresponse.com* or Oil Spill Response Limited at: *http://www.oilspillresponse.com*

Additional information on other developments in subsea well response can be obtained from various websites including:

- Marine Well Containment Company (MWCC): *http://www.marinewellcontainment.com*
- The UK Oil & Gas Oil Spill Advisory Group (OSPRAG): http://oilandgasuk.co.uk/advisory-group-secures-major-advances-in-uk-oil-spill-prevention-and-response/
- Helix Well Containment Group (HWCG): *http://www.hwcg.org*

Oil Spill Preparedness and Response Project

IOGP's Global Industry Response Group made nineteen recommendations on oil spill preparedness and response (IOGP, 2011). These were progressed in a joint industry programme (OSR-JIP) managed by IPIECA – the global oil and gas industry association for environmental and social issues (Flynn, 2016). Nineteen companies invested millions of dollars of effort in the 5-year programme to produce a completely revised and updated suite of guidelines. This includes 24 'Good

Practice Guides', plus detailed technical reports, and some key documents are listed in the Bibliography at the end of the paper. The full set of products can be downloaded free of charge from the JIP web-site at:

http://oilspillresponseproject.org

The sections that follow introduce some of the new guidance and innovative techniques that oil and gas operators should consider when developing or reviewing their response plans.

Oil Spill Preparedness - Strategy Planning and People

Successful response depends on well-trained people working to a properly developed response strategy that is adequately resourced and properly exercised. The new Good Practice Guide: '*Oil Spill Preparedness and Response: An Introduction'*, is the essential starting point for developing plans. It sets out core principles for preparedness and response, provides references to the latest information on the specific processes and techniques. The framework covers the key steps in Figure 2 and the sections that follow provide further information.

Figure 2. Five steps in preparing for response.

1. **Risk Based Plan Scenarios** – the starting point for developing plans should be identification of the potential major incidents for a particular operation and region, including the worst credible oil flow rate. These events are then used to develop a range of planning scenarios with the help of the new IOGP-IPIECA report: "*Risk Assessment and Response Planning for Offshore Facilities*" (see Bibliography).

2. **Developing Response Strategies Using 'NEBA'** – for each plan scenario, the new Good Practice Guide on "*Response Strategy Development Using Net Environmental Benefit Analysis (NEBA)*" helps to identify the optimum approach to minimize impacts on people and the environment by considering:

    a. Spill circumstances

    b. Practicalities of clean-up techniques

    c. Relative impacts of clean-up and response options

    The NEBA Guide sets out the process for making judgements of the relative importance of social, economic and environmental factors. Environmental and social sensitivity mapping, together with appropriate predictive modelling can support the contingency planning and response process. New information is available the following IPIECA documents referred to in the Bibliography:

    - *Sensitivity Mapping for Oil Spill Response*
    - *Review of Models and Metocean Databases*
    - *Validation of Models and Recommendations for their use in Oil Spill Response*

    Work is underway to develop and publish a more detailed methodology for NEBA in the future.

3. **Oil Spill Response Resources** – the plans for equipment and manpower need to comply with relevant regulations and be matched with the response strategies (updated and revised "*Contingency Planning*" Good Practice Guide available). It is also important to decide in advance which resources need to be available locally, and which can be sourced from the region or around the world by applying the latest principles of "*Tiered Preparedness and Response*" (see Bibliography). This model has evolved considerably, with modern technology, advanced logistics capabilities and new communications tools allowing specialized resources to be cascaded to the response location, avoiding unnecessary duplication.

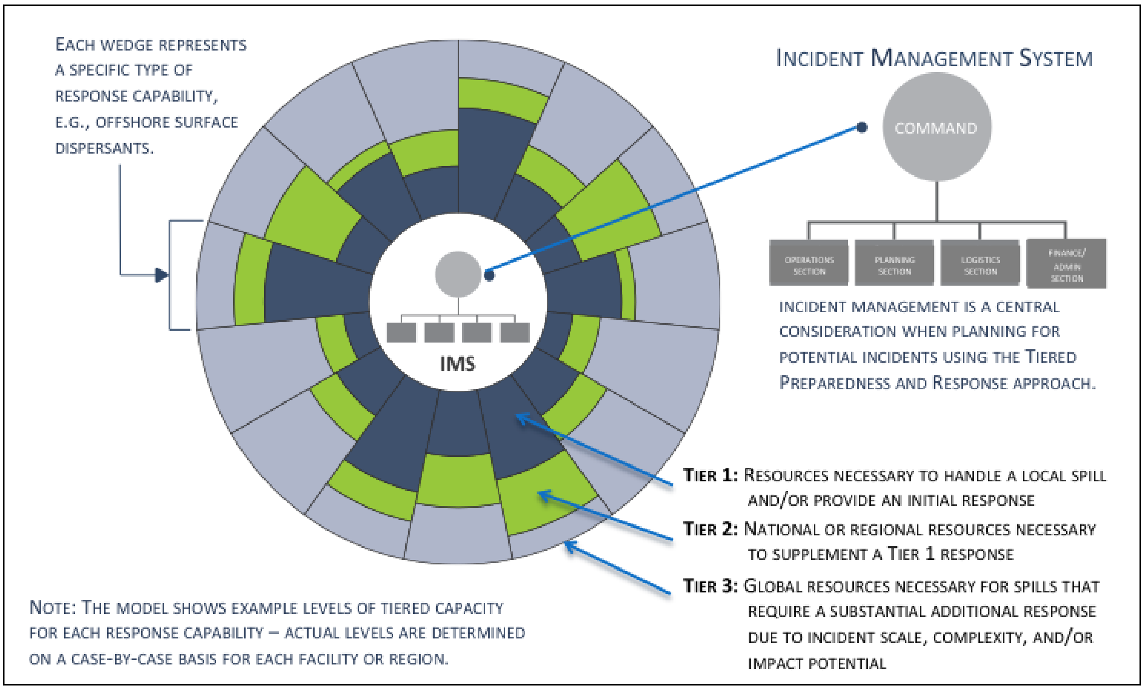

Figure 3. Tiered Preparedness & Response Model (Source: IPIECA)

4. **Incident Management System (IMS)** – this sets out the common organisation and procedures used to establish command and control of the response. IOGP and IPIECA have recently published a recommended: "*Incident Management System for the Oil and Gas Industry*", that is based on the Incident Command System (ICS) – a version of IMS widely used by industry, response contractors and emergency services organizations. This includes common organizational elements (e.g. sections, branches, divisions, etc.), management structure, terminology and operating procedures. By adopting and training responders in a single common system, the effort can be scaled-up and different teams integrated into a single unified structure. Further supporting Good Practice Guides and reports are available (see Bibliography) covering:

- *Oil Spill Training*
- *Oil Spill Exercises*
- *Oil Spill Responder Health and Safety*
- *Volunteer Management*

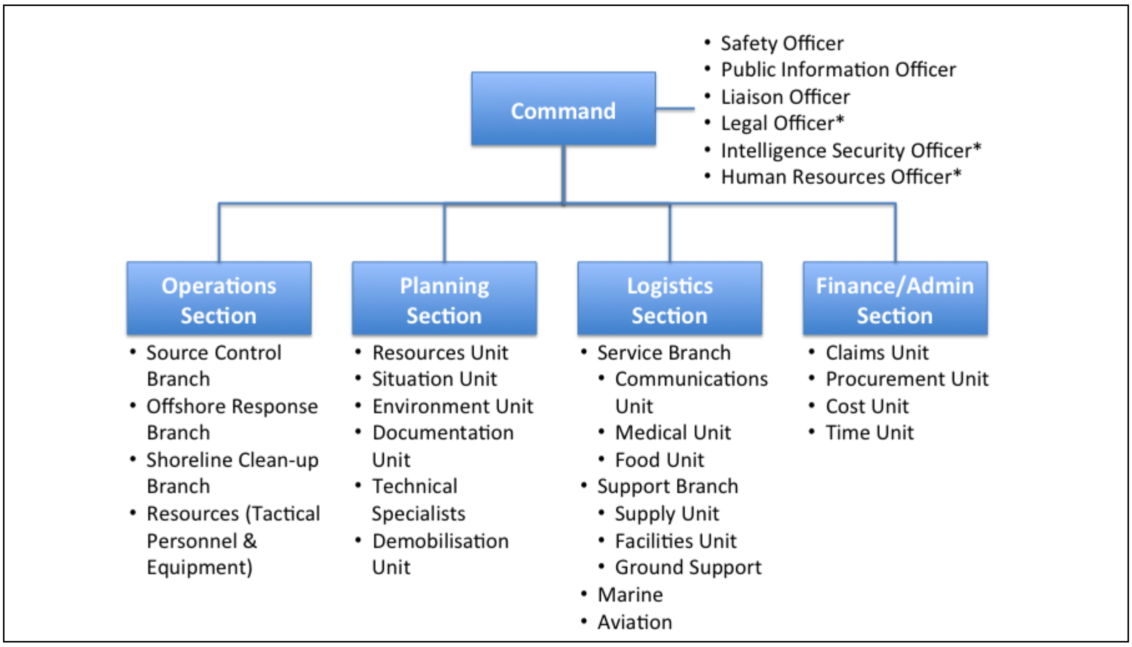

Figure 4. Example Incident Management System command structure for the oil and gas industry.

5. **Stakeholder Engagement** – companies, governments and communities need to work together before, during and following an incident. Stakeholders should be involved from the very start of planning and preparation so that there is a shared understanding of priorities and quicker decision-making. This can include pre-approval of certain response techniques and strategies to accelerate their deployment in an emergency.

New Guidance on Oil Spill Response Tools and Techniques

A number of new oil spill response capabilities were developed during the Gulf of Mexico response and more experience was gained on existing techniques. IPIECA have incorporated this learning, together with information from a range of supplementary technical projects, into fully revised and updated practical guidance. Each spill is different and dynamic, and responders need the full range of tools to be available in the toolbox (Figure 5). The technical information available from IOGP-IPIECA is comprehensive, and this paper can only highlight a few selected areas to illustrate some of the key advances made and products available. Further resources are identified in the Bibliography.

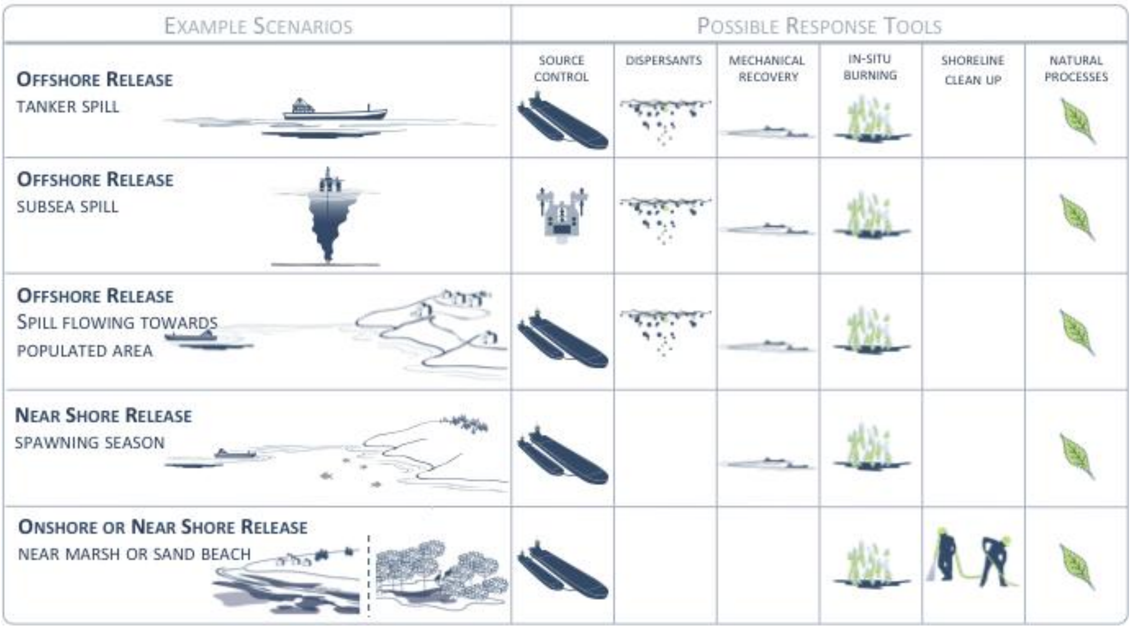

Figure 5. Typical response tools applicable to various circumstances (Source: IPIECA).

Dispersants

For offshore spills, dispersants can be rapidly deployed and are one of the most effective tools in a majority of scenarios. Dispersants work just like soap and shampoos; in fact they contain many of the same ingredients. They break the oil into very tiny droplets, which are rapidly diluted and biodegraded by naturally occurring microorganisms in the marine environment. This can avoid floating oil from impacting sensitive near-shore areas and accelerates the natural biodegradation process. New resources include (see Bibliography):

- Updated Good Practice Guide: "*Surface Application of Dispersants*", which describes dispersant mechanisms, risks and benefits, and when and how to apply them.
- New Good Practice Guide: "*Subsea Application of Dispersants*" captures the recent evolution of this technique and its potential application to deeper water well releases.
- Dispersant testing techniques for both surface and sub-sea application have been extensively reviewed (see: "*Guidelines on Oil Characterization to Inform Spill Response Decisions*").
- Comprehensive reviews of dispersant supply logistics have been conducted and industry has recently established shared stockpiles in strategic locations (see: "*Dispersant Logistics and Supply Planning*").
- The considerations and advantages of regulatory pre-approval and authorisation are set out in: "*Dispersant Licensing and Approvals*". This highlights the distinction between pre-approval – which identifies which dispersants can be used, and authorisation – which allows use their under the specific circumstances of a response.

In particular, there is now a significant body of information on the application of dispersants subsea to tackle oil release from a well-head in deeper water. Dispersing oil in the high turbulence areas close to the point of release allows a greater proportion of oil to be efficiently broken into smaller droplets that can be dispersed, diluted and biodegraded in the water column. Potential benefits compared to surface application include:

- Released oil is treated at the point of release, potentially reducing the area impacted by floating oil
- Less dispersant can be used when compared to treatment of oil spread across the water surface

- Responder safety can be enhanced by greatly reducing exposure to volatile organic compounds (VOCs) at the surface in the vicinity of the release
- Application can continue day and night, and in practically any weather conditions, unlike sea surface response techniques.

Like any response technique, the potential benefits and risks of sub-sea dispersant need to be considered in the Net Environmental Benefit Analysis, but this is an important new tool in the toolbox for certain situations.

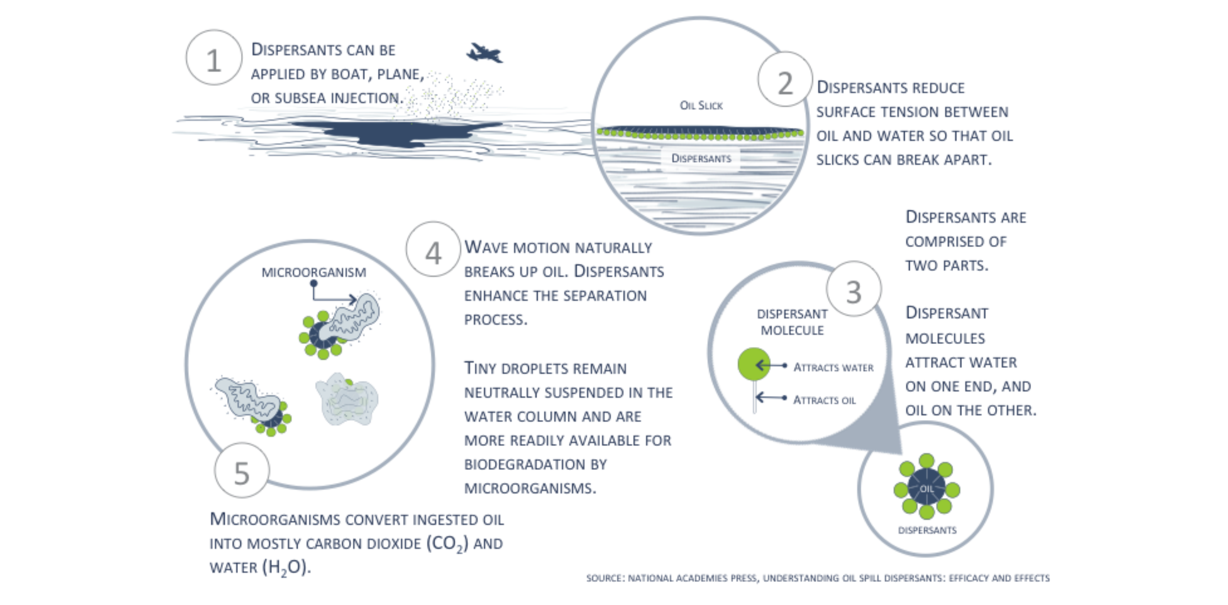

Figure 6. How dispersants affect water borne oil.

In-Situ Burning of Oil

Prior to the Macondo response controlled in-situ burning of oil on the sea surface had only been done in test burns of up to 40 minutes. Controlled burns of up to 10 hours were routinely used in the Gulf of Mexico, clearly demonstrating the importance of the technique for combatting offshore spills. Field and subsequent laboratory testing data has now been incorporated into a Good Practice Guide: "*In-Situ Burning*". This explains how and when to apply the technique, equipment design and selection for fire resistant boom and ignition systems, and operational and monitoring considerations.

At-Sea Containment and Recovery

Even well established techniques, such as boom and skimmer application, were enhanced during the Gulf of Mexico response. The IPIECA-IOGP Good Practice Guide for "*At-Sea Recovery and Containment*" provides guidance on the latest techniques, and the pros and cons of the various approaches under a range conditions.

Shoreline Clean-up and Waste Management

While a general aim of a response is to prevent spilled oil reaching the shoreline, at least some may eventually do so. In this situation, shoreline assessment becomes a critical part of the response, and the IOGP-IPIECA "*Shoreline Assessment"* Good Practice Guide supports planning, decision-making and practical implementation. The important factors to be considered when implementing clean-up of an oiled shore are set out in the companion guidance: "*Shoreline Clean-Up Techniques*".

Oiled Wildlife Response

A fully revised and updated Good Practice Guide on *Wildlife Response Preparedness* was published in 2014. This was conceived as a course manual for personnel developing oiled wildlife response plans for companies or countries and who may have less familiarity with the topic. The industry has also developed Teir-3 global response options that can support local arrangements.

Spill Surveillance, Monitoring and Visualisation

The response to the Deepwater Horizon incident took the application of spill monitoring and information management technology to a completely new level. New tools such as satellite imaging, oil-in-water sensing and the application of geospatial information systems had not previously been used together at this scale. The learning from the response has been extended through a series of follow-up technical assessments to enable these tools to be considered in future plans (see Bibliography).

a. Surveillance and Monitoring

The latest information has been compiled in a series of technical reports covering:

- *In-water surveillance* – including ocean vehicles for sub-sea and surface detection and tracking of spills, and the range of sensors for monitoring hydrocarbons in water.
- *Remote Surveillance* – practical recommendations are included for the application of satellite and airborne remote sensing in oil spill response.

b. Common Operating Picture

Geospatial information systems (GIS) were used in the Gulf of Mexico to combine disparate sources of response data into a single picture for use by both responders and stakeholders. This involved layering of diverse information such as (Fig. 7):

- Topography, infrastructure and administrative boundaries
- Environmental sensitivity maps
- Dynamically updated vessel, response equipment, and responder locations
- Weather
- Spill observations, locations and trajectory predictions

The IPIECA JIP Report "*Common Operating Picture*" recommends a suitable architecture that allows layers of information to be superimposed with actual observations from the field using mobile technology and made available to a variety of users. This includes best practices, supported by open standards that can be deployed quickly in any region of the globe.

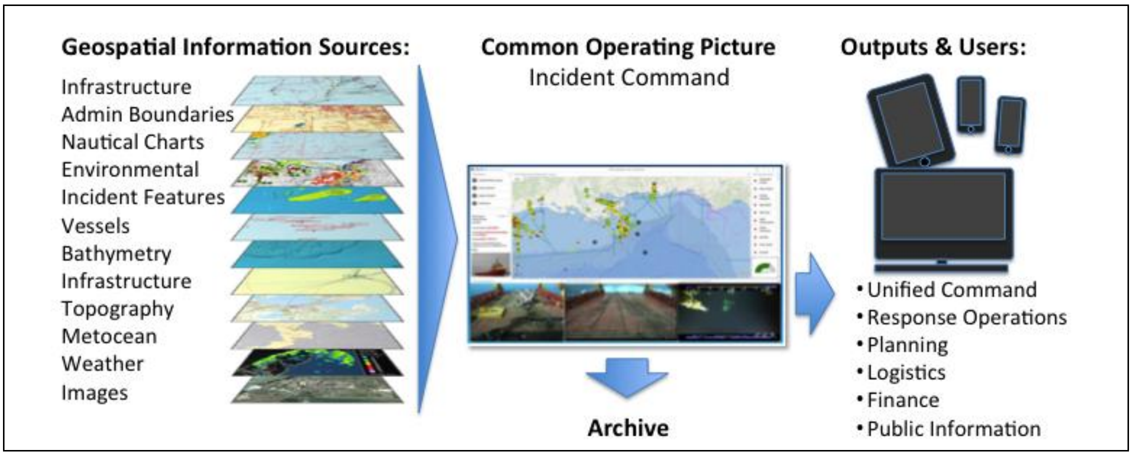

Figure 7. Common Operating Picture conceptual diagram

Summary and Conclusions

The industry has invested millions of dollars to revise and update oil spill guidance, and incorporate the learning from Macondo, Montara and similar incidents. This has produced 24 Good Practice Guides, 15 technical guides, 3 research papers and 2 Recommended Practices. Only a small subset of the newly available resources has been reviewed in this paper and a more extensive Bibliography has been included for those with further interest. The key developments and considerations include:

1. Major accident risk analysis is the starting point for developing response plan scenarios and new practical guidance has been published.
2. Net Environmental Benefit Analysis (NEBA) can be used during planning to help identify the optimum response strategies for the different spill circumstances. This is an area of on-going work.
3. Response plans should identify in advance which resources are sourced locally, regionally or globally. The latest guidance on Tiered Response and Preparedness provides an approach that can help to optimise deployment and avoid duplication.
4. The industry recommended Incident Management System (IMS) guidance should be considered when reviewing response organisation structures and procedures to enhance potential collaboration and ability to scale-up a response.
5. Fully revised and updated guidance on oil spill response equipment, tools and techniques can now be incorporated into updated response plans, and applied in training and exercises.
6. Guidance is available to support involvement of government and community stakeholders throughout the planning, response and follow-up lifecycle to enhance transparency, speed and effectiveness of response.

Acknowledgement

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IOGP 2015, Wells Expert Committee Bulletin - Issue 1, WEC01

IOGP, 2016a Recommendations for enhancements to well control training, examination and certification, Report No: 476,

IOGP, 2016b Standards and guidelines for drilling, well constructions and well, Report No: 485

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Industry sub-sea well response information can be found at the following websites:

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- Oil Spill Response Limited: *http://www.oilspillresponse.com*
- Marine Well Containment Corporation: *http://www.marinewellcontainment.com*
- UK Oil & Gas Oil Spill Response Advisory Group (OSPRAG): *http://oilandgasuk.co.uk/advisory-group-secures-major-advances-in-uk-oil-spill-prevention-and-response/*
- Helix Well Containment Group (HWCG): *http://www.hwcg.org*

Oil Spill Preparedness and Response

Selected resources on oil spill preparedness are available from the IOGP-IPIECA JIP website: *http://oilspillresponseproject.org*

Preparedness and Response Framework

- *Oil Spill Preparedness and Response: An Introduction*. IOGP-IPIECA Good Practice Guide
- *Risk Assessment and Response Planning for Offshore Facilities*. IOGP-IPIECA OSR-JIP Report
- *Response strategy development using net environmental benefit analysis (NEBA).* IOGP-IPIECA Good Practice Guide
- *Sensitivity Mapping for Oil Spill Response.* IOGP-IPIECA Good Practice Guide
- *Contingency Planning*. IOGP-IPIECA Good Practice Guide
- *Tiered Preparedness and Response*. IOGP-IPIECA Good Practice Guide
- *Incident Management System*. IOGP-IPIECA Good Practice Guide
- *Oil Spill Training.* IOGP-IPIECA Good Practice Guide
- *Oil Spill Exercises.* IOGP-IPIECA Good Practice Guide

Response

- *Health and Safety of Responders.* IOGP-IPIECA Good Practice Guide
- *Volunteer Management.* IOGP-IPIECA Good Practice Guide
- *The global distribution and assessment of major oil spill response resources.* IOGP-IPIECA OSR-JIP Report
- *Guidelines on oil characterization to inform spill response decisions.* IOGP-IPIECA OSR-JIP Report
- *Surface Application of Dispersants.* IOGP-IPIECA Good Practice Guide
- *At-sea monitoring of surface dispersant effectiveness.* IOGP-IPIECA OSR-JIP Report
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- *Inland Response.* IOGP-IPIECA Good Practice Guide
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- *Oiled Wildlife.* IOGP-IPIECA Good Practice Guide

Surveillance Modelling and Visualisation

- *Ariel Observation of oil pollution.* IOGP-IPIECA Good Practice Guide
- *Satellite Remote Sensing.* . IOGP-IPIECA Good Practice Guide
- *Capabilities and Uses of Sensor-Equipped Ocean Vehicles for Subsea and Surface Detection & Tracking of Oil Spills.* IOGP-IPIECA OSR-JIP Report
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- *Validation of models and recommendations for their use in oil spill response*. IOGP-IPIECA OSR-JIP Report
- *Common Operating Picture.* IOGP-IPIECA OSR-JIP Report

Restoration

- *Impacts of Oil Spills on Marine Ecology.* IOGP-IPIECA Good Practice Guide
- *Impacts of Oil Spills on Shorelines.* IOGP-IPIECA Good Practice Guide
- *Economic Assessment and Compensation.* IOGP-IPIECA Good Practice Guide